DOE Review of the RSVP Activities at BNL

Revised January 25, 2004

Presented to
DOE Office of Nuclear Physics
by
Brookhaven National Laboratory

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Appendices

1. Introduction

The Rare Symmetry violating Processes (RSVP) Project and Program at Brookhaven National Laboratory (BNL) is a Major Research Equipment - Facility Construction (MRE-FC) project and research program of the National Science Foundation (NSF). It was developed as a means to carry out a set of very compelling particle physics experiments at BNL's Alternating Gradient Synchrotron (AGS) machine after the U.S. Department of Energy (DOE) terminated the use of this machine as a DOE user facility in U.S. Fiscal Year (FY) 1999. RSVP at this time, consists of two separate experiments, KOPIO and MECO that will be constructed over the next several years and then operated to produce physics results.

The AGS accelerator complex is now the beam injector for the Relativistic Heavy Ion Collider (RHIC) facility, an application that requires its operation only a fraction of the 168 calendar hours each week. At the present time, this fraction is about 60% and it is our goal to decrease this to 40% over the next few years as the commissioning of the many different operating modes of RHIC is completed. It is possible to use the AGS for a separate user program, in this case the RSVP experiments, for the remaining ~ 100 hours per week during periods when RHIC runs simultaneously. If RHIC is not running, it is possible to run the AGS alone, but typically at higher per-week cost. Such multi-tasking use for user experiments has already been successfully demonstrated in the earlier data taking for AGS experiment, E949 and others. The purpose of this paper is to address the potential impacts, both positive and negative, that the RSVP project and operations program could have on the RHIC operations now in progress for DOE's Office of Nuclear Physics (ONP).

We also note an additional possible use of the AGS by a third experiment, AGS E949, another very compelling experiment that was started in FY02 under DOE Office of High Energy Physics (OHEP) sponsorship but not completed. The completion of E949 was submitted as a new proposal to the NSF (not a part of RSVP) and is under consideration for operations support at the AGS by that agency. Because this additional potential use is comparable to the RSVP experiments in its potential impacts on the RHIC program, DOE ONP asked that it be included in the review assessment, and supporting information for it will be provided in the companion white paper.

To fully assess the impacts, both positive and negative, of RSVP on the RHIC program, DOE-ONP commissioned a DOE Review of these potential impacts, headed by DOE's Daniel Lehman. The formal Charge to the reviewers, along with additional guidance for the objectives of the review, is provided as Appendix I of this paper for the convenience of the reader. This paper itself meets one of the requirements of the review guidance. It is anticipated that NSF program officers will attend the review as observers.

Finally, in this Introduction, we provide a brief guide to the main content of the paper.

In Section 2 we provide a brief synopsis of the science objectives, experimental approach, plans for the engineering design, construction and operation of each of the two RSVP experiments. Details of technical design work to date are provided in the form of web references in Appendix III.

In Section 3, we briefly discuss the plans for oversight and review by the NSF and DOE as they are presently understood.

In Section 4, we provide a general overview of the 'Work for Others' (WFO) policy and its implementation that DOE uses to characterize work done at DOE facilities for non-DOE customers (such as NSF). We explain how this policy may be applied in the case of RSVP, including the principle of incremental costs and BNL overhead policy as applied to large construction projects such as RSVP.

In Section 5, we discuss the specific impacts, positive and negative, that will or could transpire during the commissioning and operations periods for RSVP. Although there are interactions between RSVP and RHIC during the RSVP construction phase (via the involvement of C-AD staff), the simultaneous machine-use periods are the most important for this review.

In Section 6, we discuss the specific impacts on RHIC during the engineering design, construction and decommissioning/disposal (D&D) phases of RSVP. In this case, the main impacts are the needs for BNL technical manpower and project construction work needs of KOPIO and MECO and the potential imbalance between these technical needs (funded by NSF) and the equivalent requirements of the RHIC program. In all cases, RHIC activities will have priority in this area when potential priority conflicts appear.

In Section 7, we present an overall cost and funding Tables to show how NSF funding of RSVP relates to the RSVP work provided by BNL as well as for experimental operations of the RSVP. These cost/funding Tables were also required for this review in the guidance from DOE.

The material in all these sections will be presented orally during the review and opportunities provided during the parallel sessions to explore issues and questions of the reviewers.

2. RSVP Project and Program

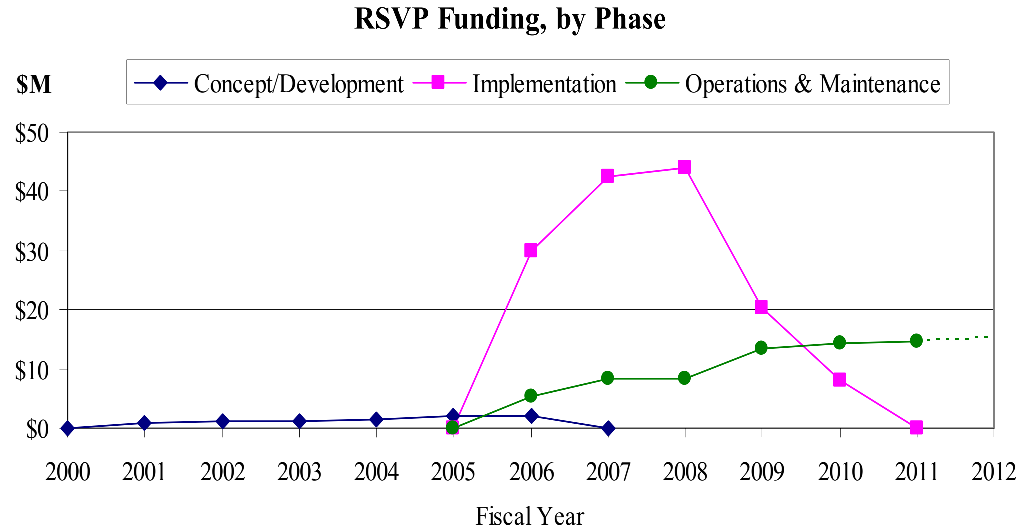
The RSVP project includes two experiments that sensitively probe the Standard Model of Elementary Particle Physics. If funded, they would carry on a tradition at the Brookhaven National Laboratory of probing fundamentally new physics at the high-energy frontier through studies of rare processes and precision measurements. The proposed MECO experiment would search for muon to electron conversion in the field of a nucleus with one event sensitivity, normalized to the muon capture rate in the same nucleus, of 2×10^{-17}. The muon to electron transition does not conserve lepton flavor. For it to occur at an observable rate new physics is required, beyond the usual Standard Model (SM) and minimal extensions that allow for light massive neutrinos. KOPIO measures the branching ratio for the neutral kaon decay $K_L^0 \rightarrow \pi^0 \upsilon \overline{\upsilon}$. KOPIO will be 100,000 times more sensitive than previous experiments, resulting in 40 or more events at the branching ratio level predicted precisely in the SM, $(2.8\pm1.0)\times10^{-11}$. KOPIO uniquely determines the Jarlskog parameter which characterizes all CP-violating observables in the SM. Discrepancies with the prediction or with similarly precise measurements in the B meson system would unambiguously indicate the presence of new physics.

Proposed for NSF MREFC support in October of 1999, the experiments were favorably reviewed for scientific merit and technical feasibility shortly thereafter, in early December of 1999, by an NSF appointed panel. There have been seven additional reviews in the three year period since, including a cost review in July of 2000, a review focusing on RSVP management in November of 2000, and technical and management reviews in May and June of 2001 by Brookhaven's Laboratory Oversight Committee (LOC) and by an NSF appointed panel one month later. The November review elicited a clear response from the RSVP collaborations and from BNL on better definition of the oversight role of the BNL Associate Laboratory Director, as well as a BNL and MECO Collaboration agreement on an acquisition plan for the MECO magnets, the costliest system in RSVP and the one whose design and construction drive the MECO schedule. The November committee report urged the MECO collaboration to solicit quotes and then proceed to issue a contract for the conceptual design of the magnet system. The contract was won by the MIT Plasma and Science Fusion Center and the conceptual design completed and documented in a 300 page report in February of 2002. There have been three external reviews of this effort: an interim review in September of 2001, a final review in February of 2002, and a review by the Magnet Acquisition Panel convened in September of 2002 to advise the RSVP Principal Investigator on the method of acquisition. A very positive outcome of this process was that the MIT group has agreed to oversee the engineering design and construction of the magnet system. A productive meeting to discuss safety issues related to the magnet system, with the MIT designers and BNL experts participating, took place in June of 2003 at BNL. Technical designs and development in other areas are documented in the MECO and KOPIO Technical Design Reports, and in internal technical reports.

Both experiments have made strong starts, despite limited funding. KOPIO, especially, has made progress in seeking supplements to its funding with foreign contributions. The National Sciences and Engineering Research Council of Canada (NSERC) has provided C$0.6M for KOPIO R&D and has committed another C$1.8M for construction once MREFC funding is approved (the C$ is lately at 0.78 US$). These grants are for capital expenses, carry no overhead, and are in addition to substantial TRIUMF and NSERC labor contributions. The Canada Foundation for Innovation (CFI) awarded the University of British Columbia C$7.2M for upgrades of the AGS required by KOPIO: the RF cavities for micro-bunching and the kicker magnets and power supplies for increasing the intensity from 70 to 100 Tp/pulse. The award is contingent on the project receiving Congressional approval in FY2004, but the expectation is that CFI will be flexible through some delays, as long as RSVP funding appears likely. Foreign contributions from Japan, estimated at US$2.2M, and Switzerland, US$0.7M, are expected and would add to the total.

Funding to RSVP for R&D has been provided up to now in three grants from the National Science Foundation to RSVP universities. They went to the University of California at Irvine (UCI) for MECO, and to Yale and Stony Brook University (SBU) for KOPIO. Subawards from these institutions re-distribute the funding where it is needed. The amounts for MECO/KOPIO have been $1.5M/$1.2M for the three year period 5/1/01 through 4/30/04 to UCI and Yale, and $1.2M and $1.0M, split equally between the experiments to UCI and SBU, for the periods 10/01/02 through 9/30/04 and 9/01/03 through 8/31/04 respectively. These are in addition to university grants provided by the NSF and DOE to the participating institutions.

MREFC funding has been approved at every level of the NSF, as detailed in a letter from the Assistant Director for Mathematical and Physical Sciences to the RSVP Principal Investigator: “First, the initial proposal was peer reviewed and found to have outstanding prospects for major advances in our understanding of some of the most important questions in fundamental particle physics. Second, RSVP was critically reviewed internally at NSF by senior management from all of the NSF Directorates, resulting in broad, strong support for going forward. Third, RSVP was selected by the NSF Director as a project whose scientific goals and readiness warranted consideration by the National Science Board. Fourth, the National Science Board reviewed the case for RSVP and approved it for inclusion in the FY 2002 or later budget.” The RSVP project appeared in the President’s FY 2004 Budget Request to Congress (see figure below) with a start scheduled for 2006. MREFC funding will be provided to New York University, the institution that submitted MREFC proposal to the NSF, and distributed to the participating institutions through subawards. This is in keeping with NSF policy to empower the university community to take a leadership role in all aspects of the scientific endeavor, from design through construction and operation.



3. Oversight and Management of RSVP

The NSF will provide oversight through an assigned NSF program officer as described in the draft Management Plans of the KOPIO and MECO projects. In addition to this, the NSF has designated the BNL Associate Laboratory Director for High Energy and Nuclear Physics (ALD-HENP) as the Laboratory Oversight Officer for RSVP. This is an advisory role but is not in the direct management line. It is understood that the ALD is responsible for appointing a "Laboratory Oversight Committee" (LOC) that will aid the ALD in assessment and oversight of the RSVP project and program. The RSVP LOC was appointed in 2001 and held its first review of RSVP in May 2001. In pursuit of this oversight role, the ALD and LOC will hold further periodic reviews of the RSVP activities and provide advice and recommendations to the NSF and to the KOPIO and MECO management as needed.

The BNL-managed parts of the RSVP Projects will be overseen for DOE by an on-site Project Manager (PM) appointed by the DOE Brookhaven Area Office (BAO) Site Manager, Michael Holland. The DOE-BAO PM is anticipated to be Mr. Michael Butler. The oversight role of the BAO and its relationship to NSF and BNL for the RSVP activities are spelled out in a draft Memorandum of Understanding (MOU) between the two agencies. It is anticipated that the two agencies will conduct joint progress reviews of the RSVP to ascertain status and provide guidance on the projects.

The KOPIO and MECO MRE-FC Projects will each be managed by a Project Manager, appointed by their collaboration with the concurrence of the NSF and BNL. They will also maintain close communication with their respective collaborations through mechanisms established in the collaborations and with the BNL ALD-HENP as needed to meet the oversight conditions. Appointment of the two RSVP project managers has been accomplished. Dr. Michael Hebert of the University of California, Irvine, is the MECO PM and Dr. Michael Marx of Stony Brook University is the KOPIO PM. Their roles and responsibilities are described in the draft Management Plans of the two collaborations. The two PMs will be responsible for management of the entire KOPIO and MECO projects, not just the aspects that relate to BNL and involved in the present review.

The KOPIO and MECO experimental operations at the AGS will be overseen for NSF, DOE and BNL by the ALD-HENP and these will transpire under the normal BNL operations procedures and controls for AGS experiments. Most of these conduct of operations systems are based in the Collider-Accelerator Department (C-AD) but other BNL administrative units, such as the Physics Department, RHIC-AGS Users Office and the Instrumentation Division are also involved in aspects of the commissioning and data-taking phases of the experiments. There are well-established controls for all aspects of these operations that ensure safe and secure operations plus protection of the environment under a long-established Conduct-of-Operations methodology for C-AD experiments.

4. Work for Others (WFO) at AGS – NSRL Experience

The U.S. Department of Energy (DOE) laboratories allow for the performance of work for organizations other than DOE, as well as a methodology for the costing and oversight of such work. The system for performing such work is called the Work-for-Others (WFO) protocol. Such WFO work has been performed routinely and successfully in the Collider-Accelerator Department (C-AD) for many years for a variety of customers, including both MECO and KOPIO. A good model for RSVP activities in C-AD's RHIC accelerator complex is the recent and ongoing work for NASA's Radiobiology Program at BNL. The construction of the NASA Space Radiation Laboratory (NSRL) at BNL and its subsequent operations for radiobiology users transpired under WFO protocols.

The RSVP Project scope includes the construction of two NSF supported experiments, KOPIO and MECO, including the modifications to the AGS, the injector to the DOE supported RHIC accelerator, and to the proton beam transport, secondary beam lines and experimental areas. Since the financing of the construction and operations of RSVP will be through the NSF, but operated at a DOE facility, the RSVP Project and operations will be handled under a WFO arrangement. We describe in the following text, the planned approach for all work that will be performed under the auspices of the Collider-Accelerator Department (C-AD), the BNL organization that is responsible for all activities at the complex of accelerators that constitute the RHIC facility.

The RHIC facility consists of seven linked accelerators that provide beams for programs at the Tandem Van de Graaffs, Linac, Booster, AGS and RHIC. All seven machines are used for RHIC operations, with the AGS as the injector to the two RHIC accelerators. The RSVP proton program requires the use of the chain of machines from the Linac to the Booster and the AGS, which subsequently delivers a slow extracted proton beam to the experimental target stations. In addition, there is a separate user program at the Booster, the NASA Space Radiation Laboratory (NSRL) that uses mostly ion and some proton beam. The Linac supplies proton beam to BLIP for isotope production (DOE NE). Only those Linac pulses, operations is at 7.5 Hz, which are not needed by other programs are sent to the BLIP target station. The two Tandem Van de Graaff accelerators provide heavy ion beams to commercial users when their services are not needed for either RHIC or NSRL.

It is useful to review the process that was used for the recently successfully completed NASA Space Radiation Laboratory Project and the subsequent beam operations of the NSRL facility for radiobiology users in some detail. NASA presently supports NSRL operations on an incremental cost basis to RHIC operations. The additional personnel, electrical power, material purchases, purchased services, equipment and overheads to operate the accelerators, experimental area and support laboratories within the Medical Department are supported completely by NASA. In addition, NASA contributes escrow funds for future decontamination and decommissioning (D&D) costs as well as a 3% tax to DOE for non-DOE federal projects. The NSRL program is operated in a mode unlike that of either a nuclear or high energy physics program. Operations consist of 5 days per week of 8 – 10 hours per day shifts. The total expected operation is approximately 800 – 1200 hours per year that are split into three running sessions.

NSRL is the latest accelerator project completed by C-AD and is an excellent example of how well a work-for-others contract arrangement can work. NSRL was a NASA supported construction project that was completed, on-schedule, in June 2003 and below the budgeted cost of $34M. The C-AD part of RSVP is expected to have a capital cost that is comparable to the NSRL effort. The construction of NSRL, which was previously called the Booster Applications Facility (BAF) Project, consisted of the installation of a Booster slow extracted beam system, a 100 meter beam transport system and equipment support building, an experimental area and support building and experimental support apparatus at both the NSRL facility and at the BNL Medical Department. This was managed as a WFO project. BNL applied the G&A overhead rate for large projects to the NSRL Construction Project. BNL intends to apply this large project overhead rate in the construction of RSVP. The operations costs will bear the standard BNL G&A overhead rate.

Prior to the start of NSRL construction in 1998, NASA and DOE signed a formal Memorandum of Understanding (MOU) to construct an accelerator-based facility for NASA at BNL. This memorandum, which was signed by the NASA Office of Life and Microgravity Science and Applications and the DOE Office of High Energy and Nuclear Physics, provided the basis for the joint NASA-DOE arrangement. Prior memoranda of understanding had been signed to establish cooperation on the Space Exploration Initiative (1990: Truly and Watkins), to provide ion beams at the AGS (1992, 1994) . Ion beams have been available for NASA since 1995 at the AGS. During the NSRL construction period that began in 1999 and continues into the present, the Johnson Space Center has had the NASA oversight and program guidance role. The DOE Office of Nuclear Physics has represented the Department interests to date. The DOE Brookhaven Area Office Project Manager provided daily construction management oversight.

The construction project was carried out under prevailing DOE rules, combined with NASA and DOE oversight, and engendered minimal to no interference with RHIC activities. C-AD provided a management plan, a work-breakdown-structure, a schedule and a cost estimate. The C-AD environmental, safety, security and environmental (ESSH) activities included NEPA documentation, an Environmental Assessment document resulting in a finding of no significant impact (FONSI), a Safety Analysis Document (SAD), a series of Accelerator Readiness Reviews (ARR) and daily ESSH oversight of construction activities. There were no NSRL related injuries during the construction period. The reporting of construction project status consisted of equivalent parallel paths to NASA, DOE BAO and to DOE ONP. A monthly status report on progress, technical, cost and schedule was generated. NASA-DOE on-site Annual Project Reviews, run by the Office of Science Construction Management Support Division, covered progress to date, technical status, cost and schedule. C-AD conducted weekly staff meetings to discuss management issues, technical progress, schedule and cost issues. Several planning meetings during the life of the project were held with representative potential NSRL users to develop the details of the experimental areas and the equipment needed to support the experimental program. A most important aspect that insured success was the active communications between NASA headquarters, NASA JSC, DOE BAO and BNL. Frequent visits, meetings and telecommunications were essential.

The close communication among NASA headquarters, NASA JSC, DOE ONP and BNL continues into the operations phase of NSRL. Operations funding for the NASA radiobiology program is requested yearly by BNL through a statement of work to NASA JSC. Program direction is through NASA JSC and NASA Headquarters. Experimental proposals for NSRL are solicited through published calls by NASA and are reviewed by NASA selected panels before being reviewed for NSRL scheduling by the BNL Scientific Advisory Committee for Radiobiology (SACR) and then scheduled by C-AD. NASA JSC intends to initiate a yearly review of NSRL operations in conjunction with the yearly DOE NP program review.

The scheduling of radiobiology experiments is treated differently than physics experiments because cells and animals have strict pre-beam-exposure time constraints. The established C-AD priority principles ensure that RHIC operations receive first priority. To date, C-AD has managed to schedule NSRL operations outside of RHIC physics operations. The first joint operation is scheduled for March 2004. C-AD intends to operate NSRL concurrently with RHIC injection, an operations mode that was established during the November 2003 NSRL experimental run. For NSRL experiments, all accelerator related operations are the responsibility of C-AD, including dosimetry support. The life-science support aspects for cell and animal experiments are the responsibility of the BNL Biology and Medical Departments.

The construction, installation and operations aspects of RSVP are planned to be handled in a WFO manner similar to that for NSRL, and consistent with the RSVP management plan. RSVP consists of two large detector systems that are the primary responsibility of the individual collaborations. All the accelerator and beam related construction and experiment installation are be the responsibility of C-AD, although some of the work may be done by the RSVP collaborating institutions. AGS machine modifications will be accomplished during major RHIC shutdown periods and thus not interfere with operations. Beam line and experimental equipment installation will not interfere with operations. The ES&H oversight and documentation and the large experimental structure installation will be the responsibility of C-AD. Memoranda of Understanding (MOU), between C-AD and KOPIO and between C-AD and MECO, will define the responsibilities and deliverables between each collaboration and C-AD. This is standard procedure for all major AGS experiments. C-AD will provide a management plan, work-breakdown-structure, cost plan and schedule within the project management structure (WBS) for each experiment. C-AD will contribute to monthly reports of status of the experiments that each of the KOPIO and MECO Project Managers will produce. DOE BAO will provide project management oversight at BNL for NSF and DOE.

KOPIO and MECO will be run concurrently with RHIC operations either by mode switching or by pulse-to-pulse modulation (PPM). The ALD for Nuclear and High Energy Physics will determine the running priority between the two experiments with the advice of the BNL HENP Program Advisory Committee. C-AD will implement the schedule for running the two experiments. RHIC operations will have precedence over the concurrent AGS operations when repairs and maintenance are needed to continue RHIC operations. RHIC injection will have priority over RSVP operations should there be difficulties with fixed target operations. RSVP operations costs are assessed on an incremental basis to the base program support provided by the DOE Office of Nuclear Physics for operation of the RHIC Program. C-A currently receives no base program funding from the DOE Office of High Energy Physics or from the National Science Foundation. This cost assessment approach was first applied to the AGS nuclear physics fixed-target program in the 1980s and continues to the present day for the NASA radiobiology program.

5. RSVP Commissioning and Operations

a. AGS

Commissioning and operation of RSVP will mostly take place concurrently with the operation of RHIC. This is possible since during a typical 4-hour store, with beams colliding at full energy in RHIC, the injector complex, consisting of the Tandem and Linac pre-injectors and the Booster and AGS synchrotrons, is idle. The 4-hour store length is presently determined by Intra-Beam-Scattering (IBS) that leads to a typical luminosity lifetime of about 2 hours. A future luminosity upgrade of RHIC consists of full-energy electron cooling to counteract IBS (RHIC II). Even in this case the store length will be about 4 hours due to direct "burn-off" of the gold beam at the four RHIC collision points.

At the end of a store the super-conducting RHIC magnets are ramped to injection energy and each of the two RHIC rings is refilled with up to 111 bunches. Even though the actual filling time is only about 5 – 10 minutes a full hour is allocated to allow for tune up of the injector performance.

The AGS complex has long had multi-user capabilities even before its use as RHIC injector. This capability allowed for fast and accurate switching of all control points of the complex between four different modes of operation. The switch can be accomplished between two AGS or Booster pulses and is therefore referred to as pulse-to-pulse (PPM) modulation. Each mode of operation is tuned up to maximum beam performance and then loaded either synchronously (repetitive) or asynchronously (on demand). This feature has been used routinely and very successfully for e.g. early RHIC commissioning during AGS Slow-Extracted Beam (SEB) operation, g-2 Fast-Extracted Beam (FEB) commissioning during SEB operation, and most recently for beam operation for the National Space Radiation Laboratory (NSRL) during AGS set-up for RHIC operation.

More recently a somewhat expanded "mode switching" was developed that allowed slower devices such as stripping foil changers and solid core magnets to be included. In this case a script automates the whole switching process that now typically takes about 2-5 minutes depending on the slowest device. This "mode switching" has successfully been used to operate high intensity SEB for E949 as well as polarized proton commissioning in the AGS during RHIC stores. This is the mode presently planned for the commissioning and operation of RSVP. We are investigating the possibility of implementing faster PPM switching between high intensity RSVP running and RHIC injection to further increase the availability of the AGS for RSVP. This may be particularly important if even shorter RHIC stores are needed.

Mode switching between high intensity RSVP running and polarized proton injection into RHIC will take about 10 minutes because the superconducting Siberian snake in the AGS will have to be ramped to zero field for high intensity beam. However, RHIC stores with polarized proton collisions are not limited by IBS and therefore have much longer stores of about 8-10 hours.

The AGS complex has operated at the world's highest mulit-GeV proton intensity of $7x10^{13}$ protons per pulse and has still maintained an activation level that allowed maintenance by hand. This was achieved by limiting losses and proton throughput so that the machine activation stays below a pre-set level. It is planned to continue this policy and it is expected that the performance requirements for both MECO and KOPIO can be met within these limits. Nevertheless, there will be enhanced activation of the accelerator components of the Booster and AGS and "cool-off" periods of a few hours will be needed before particularly activated areas can be accessed. This can impact RHIC operations if emergency repairs of the injector are required. On the positive side, due to the continuous operation of the injector complex any equipment failure will be detected and corrected immediately instead of only by the time of the next filling period for RHIC leading to better injector uptime for RHIC.

Reduced lifetime due to radiation damage of especially exposed components will be mitigated by preventive replacement. It is expected that one or two Booster magnets will have to be replaced every year. Also, the extraction elements of both the Booster and the AGS will have to be replaced at least once during the RSVP experiment.

b. KOPIO

KOPIO requires two key improvements in AGS performance to attain its scientific goals. These are an upgrade in beam intensity and development of micro bunch structure of the beams to permit time of flight measurement of the decaying K_L to extract its momentum.

To achieve the ultimate sensitivity required KOPIO proposes to upgrade the AGS intensity to 100Tp per pulse delivered over a spill of approximately 3 seconds. This translates to 3.57 K_L decays per micro bunch, or about 1 K_L decay in the instrumented decay volume. Both the intensity and spill length are at a flat optimum. Variation of intensity from micro bunch to bunch should not present a problem - just a loss of duty factor - for both lower than average bunches (fewer decays) or higher than average (vetoing multiple decays)

KOPIO requires a micro bunch width of 200-250 ps every 40 ns, with no more than 0.001 of protons extracted between the micro bunches. Tests with a low-voltage 93 MHz cavity achieved <250ps micro bunch width with percent-level extinction. These tests allowed development of a simulation tool that can reproduce the experimental results and is being used in the design of the final system. So far it indicates that designs with acceptable micro bunch width at 25 MHz can be realized, but meeting the extinction requirements remains a challenge. Beam tests to further refine the simulation and demonstrate design features are therefore critical. These require significant preparation and running time because measuring extinction at the 0.1% level is non-trivial.

Micro bunching beam studies were started in FY 2002 during the last AGS fixed target run. While the required bunch structure has essentially been achieved we have not yet achieved the extinction requirement - it was one of the key points to be studied in the 2003 test run that was cancelled due to lack of funding. The KOPIO experiment priority for FY 2004-5 is to finish these studies using the D6 secondary beam line. These studies will begin once the RHIC run is completed and will allow the specifications for the KOPIO RF cavities to be set. The tests include:

- Interbunch extinction studies (93 MHz and 2 MHz): 15 shifts at low intensity (~1Tp) and 5 shifts at higher intensity (~>10Tp) to extrapolate anticipated performance
- Harmonic cavity studies (2 and 4 MHz), crucial to help determine whether we need the 100 MHz cavity or not: 15 shifts at low intensity
- Cavity voltage studies (2MHz): 10 shifts at low intensity.

The next priority for the experiment is development of a neutral beam test facility. We need medium to high instantaneous intensity to test a prototype target, high intensity beam instrumentation, and calibration of the simulations of the target, spoiler, sweeper, and collimator system designed for KOPIO. Low intensity beam can be used for the studies of detector prototypes and continued optimization of inter-bunch extinction. This could be done in the D-line in CY04/05 if funds and beam time are available or could be postponed until the B-line primary beam is ready.

The requested schedule completes construction of the neutral beam 27 months after the capital start and includes the experimental area (i.e. pit and shielding). The tests could be done at night and weekends to avoid conflicts with experiment construction. The plan assumes the following AGS time table for new equipment installation in the AGS:

- 25 MHz cavity installed 12 months after construction start (assumes CFI funds are available in 2004)
- 100 MHz cavity and new kickers available at 24 months

Engineering runs are proposed to start 36-42 months after start of MRE construction. Preliminary measurements are being considered - roughly one month in duration - with a subset of the detector systems. Intensity improvements and micro bunching studies will continue as required.

High intensity (>70TP) and fully micro bunched beam tests are proposed by end of the fourth year of construction. At this point a majority of detector construction will be complete with all detector systems available after 54 months.

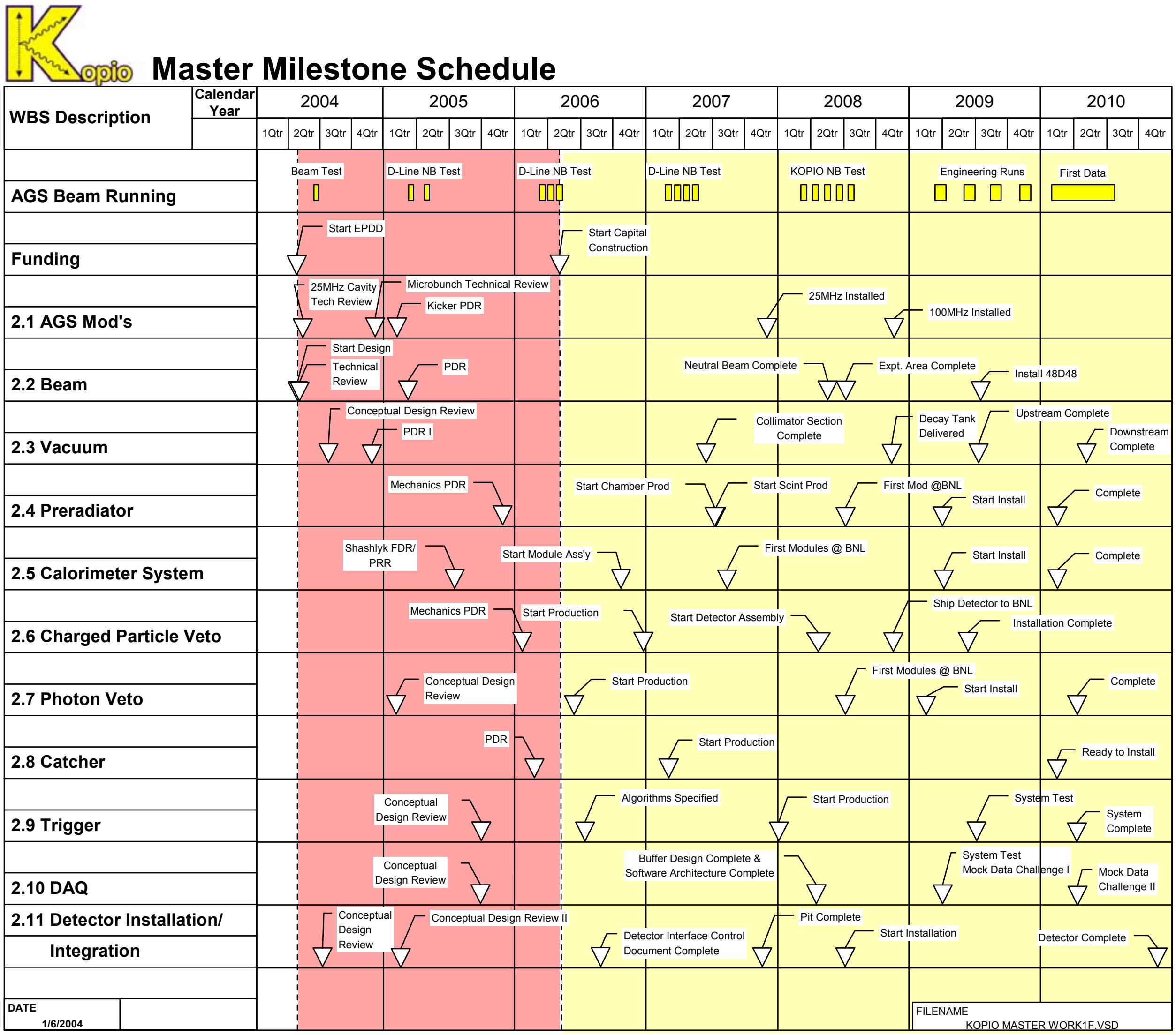
KOPIO will also benefit from access to a low energy test beam for detector development. Two 1-week runs/year beginning in 2005 are envisioned. These needs will likely be met using beams from the Booster to the new NSRL facility.

A rough test and commissioning timeline follows:

	Task	Shifts*
• 2004	Extinction	20
• 2005	RF	25
	Neutral Beam Test	
	Target, Instrumentation	
	Test Beam	14
• 2006	Neutral Beam Test /RF	20
	Test Beam	14
• 2007	Neutral Beam Test	80
	Kicker Commission (CFI)	
	Detector Testing	
	Test Beam	14
• 2008	Primary/Neutral Beam	80
	Detector Testing	
• 2009	Engineering Runs	100
• 2010	Start Data Taking	

*During all the machine development time, these are 12-hour shifts, separated by 12 hours of off-time.

The following chart shows significant milestones for 3 years of EPDD funding starting in FY04 and a FY06 capital construction start



c. MECO

The goals of MECO commissioning activities are to demonstrate that the AGS proton beam will meet MECO requirements and to develop operating procedures to allow for full intensity, properly structured beam throughout the operational period. There are three general MECO beam requirements;

a. Beam energy of ~8 GeV
b. A total beam intensity of 4×10^{13} protons/s
c. The beam must be pulsed (a.k.a. mini-bunched) with ~50 ns long pulses separated by 1.35 μs quiet intervals. Elimination of prompt experimental backgrounds requires that less than one proton for every 10^9 reaching the MECO production target arrives between beam pulses.

The nominal scheme to achieve the required time structure consists of filling two (of six) equally spaced bunches in the AGS and slow extracting the beam, still bunched. Meeting the beam intensity requirement thus necessitates 2×10^{13} single bunch intensity in the AGS. Although the overall intensity of the 4×10^{13} is modest by AGS standards, the AGS has demonstrated a maximum of only 1.2×10^{13} protons/bunch thus far. Space charge effects and momentum aperture restrictions during transition drive the current single bunch intensity limit. Both of these will improve substantially during MECO operations in that only one Booster transfer is needed, reducing accumulation time from 800 ms to 133 ms, and the 8 GeV beam energy is below transition in the AGS. There is concern, however, that hardware modifications may be required in the Booster to reach the intensity goal, hence early studies of single bunch intensity are needed to develop a plan and make the necessary changes.

Although operating the AGS at 8 GeV ameliorates space charge effects during accumulation, it may also run into difficulties at high intensity. Specifically there is concern that the existing vertical extraction aperture may be too small at these low energies. If true, we will likely be driven to modify the existing septa in the extraction line to reach full intensity on the MECO production target. Once again, early studies of this problem are needed to determine if long lead-time hardware changes are required.

Achieving the inter-bunch extinction requirement of below 1 part in 10^9 is generally considered the most challenging aspect of the MECO beam and thus much of the commissioning studies time is dedicated to understanding this issue. Measurements of the beam extinction were made in 1996 and 1999 using existing AGS hardware and the E871 and E787 detectors respectively (see the MECO Draft Technical Proposal for details). The tests demonstrated extinction rates of approximately 10^{-7} and showed that protons caught in the unfilled AGS buckets are the dominant contribution to the inter-bunch intensity. There was insufficient time for detailed beam tuning in these tests, thus it remains possible that tweaking alone will achieve the required extinction. However, the critical need to eliminate prompt backgrounds in MECO has led the experiment to take a belt and suspenders approach to improving extinction with the addition of two hardware systems, one internal to the AGS, the other external. The internal system will consist of an AC dipole magnet that will drive particles out of the beam and an adjacent kicker that will cancel the dipole field only during the passage of the two filled buckets. The detailed requirements for this hardware will be established by initial studies, followed by evaluation of the performance of the hardware at the end of the second year of MECO construction. The external extinction improvement and monitoring system consists of an RF modulated magnet (RFMM) and two subsequent Lambertson magnets. Transport to the MECO primary target is possible only when the RFMM is at peak field, and the frequency and synchronization are chosen to allow the passage of beam bunches, while deflecting particles arriving at other times into a diversion channel in the Lambertson magnets. Detectors in the diversion path will monitor the effectiveness of the AGS internal inter-bunch cleaning hardware. A prototype module of the RFMM system will be tested in conjunction with the AGS internal hardware at the end of the second project year, while the full RFMM will be installed and tested in the third project year.

In addition to studies of the AGS beam performance, MECO will require additional beam time to test prototype detector elements at low intensity, and brief periods of high intensity beam to test the production target design. Engineering running with the full detector system will take place in the fourth year of MECO construction and full scale physics data collection will begin in the fifth year. The following table summarizes the current estimate of MECO beam needs during the development and commissioning phases.

FY	Tasks	AGS* Shifts
04	Study low energy extraction and mini-bunching without AGS hardware modifications	17
05	Single bunch intensity studies Mini-bunching studies Detector prototype tests	18 3 15
06	Combined mini-bunching and high single bunch intensity Production target heating tests at high intensity Detector prototype tests	13 12 30
07	Extinction study with AGS internal hardware modifications Beam line commissioning and prototype RFMM module test Detector calibration	20 40 30
08	Test extinction with full RFMM installed Detector calibration	40 60
09	Engineering Run	100

*During all the machine development time, these are 12 hour shifts, separated by 12 hours of

In addition to beam needs, MECO will require early operational support for cryogenics engineering and technicians as well as power and consumables associated with operating the 700W refrigerator/liquefier (R/L) for the superconducting solenoids. The R/L will be installed 18 months after the start of MRE construction and will be in near continuous operation thereafter.

6. RSVP Design, Construction and D&D

a. AGS

There are only a small number of construction items for the injector complex. The first consists of an upgrade of the Booster-to-AGS transfer line from nominally 1.5 GeV to an energy of 2 GeV to reduce space charge effects and therefore beam losses during the accumulation of beam from the Booster in the AGS. The main components of this upgrade are an upgraded pulse-forming network for the Booster extraction kicker and a second section of the AGS injection kicker. This upgrade will also provide more flexibility for providing the high brightness beams for RHIC. The second item consists of one or two rf cavities for the micro-bunched slow extraction required for KOPIO. Space for these cavities has been allocated in the AGS lattice without interfering with the RHIC needs. Lastly a system to clean residual beam from between bunches during slow extraction for MECO will be installed. It consists of an upgraded AC dipole magnet a new power supply for the existing strip-line kicker. The installation of all these items can easily be accomplished during the standard three-months RHIC shutdown period.

b. KOPIO

KOPIO Project Description:
The KOPIO Construction Project comprises the fabrication and construction of a high intensity proton beam, a neutral kaon beam line and detector to obtain a measurement of direct CP violation via the decay $K_L^0 \rightarrow \pi^0 \upsilon\overline{\upsilon}$. The beam construction effort consists of a design, fabrication and installation effort to provide a microbunched proton beam via two RF cavities, and to extract and direct it onto a target to produce a neutral beam where the design, fabrication and installation effort will produce the elements necessary to collimate a neutral beam, a sweeper magnet to remove converted gamma rays and charged particles from the beam for the KOPIO detector, and shielding to reduce unwanted backgrounds produced by the primary beam. The Project effort for the detector consists of a design, fabrication and installation effort to construct the various detector sub-systems described below. Finally, the KOPIO Construction Project includes the effort to oversee and manage the cost, schedule, integration, quality assurance and ES&H for the project duration.

KOPIO Accelerator Upgrade:
For the KOPIO experiment, three upgrades to the AGS are will be carried out by a collaboration of accelerator experts at BNL and TRIUMF: extraction of a micro-bunched proton beam, increasing the proton intensity by a factor of 1.5 or more to 10^{14} protons (100 TP) per AGS cycle, and constructing a new proton beam line to bring the intense micro-bunched beam to a new K meson production target. All three items will involve collaboration between BNL and TRIUMF/UBC while the proton beam line will be produced entirely by BNL. Part of this work involves upgrades to the booster extraction kicker magnet and the AGS injection kicker magnet to deliver the increased kick strength required for proper 2.0 GeV operation of the extraction/injection system. In addition, beam dynamics simulations will be performed. These upgrades to the AGS will be beneficial to many experiments. The micro-bunching radio-frequency cavities and work related to the intensity upgrade of the accelerator will be partially funded by a $5M grant from the Canada Foundation for Innovation. Preparatory work on these projects is proposed prior to the FY2006 start of construction and initial installation and testing will occur beginning in FY2006.s

KOPIO Detector Description:
The detector consists primarily of a vacuum system, a pre-radiator, and calorimeter system and a charged particle and photon veto systems. The vacuum consists of a high vacuum segment, which will contain the decay events of interest, and a low vacuum system, which will minimize downstream interactions. The pre-radiator system consists of 32 modules constructed of dual-coordinate drift chambers, scintillators, and layers of lead and copper. The pre-radiator will convert gamma rays and measure their directions. The calorimeter system consists of lead-scintillator “Shashlyk” modules to measure energy. The photon veto is a lead/scintillator sandwich that is read out by wavelength-shifting fibers and phototubes. The charged particle veto is designed to eliminate charged particle with very high efficiency. Finally, the beam catcher is a veto system used directly in the beam to detect and veto remaining photons.

KOPIO Methodology:
Using current estimates for SM parameters, the branching ratio for $K_L \rightarrow \pi^0 \upsilon\overline{\upsilon}$ is expected to lie in the range (2.8 +/- 1.0) x 10^{-11} [6]. The experimental aspects of measuring $K_L \rightarrow \pi^0 \upsilon\overline{\upsilon}$ are quite

challenging. The mode is a three-body decay where only a π^0 is observed. There are competing decays which also yield π^0*'s*, but whose branching ratios are 10^8 larger. A detection technique must be adopted that provides maximum possible redundancy for this kinematically unconstrained decay, an optimum system for insuring that the observed π^0 is the only observable particle emanating from the K_L decay, and that has multiple handles for identifying possible small backgrounds that might simulate the signal. The current experimental limit, 5.9 x 10^{-7} [7], comes from a Fermilab experiment which employed the Dalitz decay $\pi^0 \Rightarrow \gamma\, e^+e^-$. Further improvement in sensitivity by perhaps an order of magnitude may be expected during the next few years [8]. Thus, an experimental improvement in sensitivity of more than four orders of magnitude is required to obtain the signal for $K_L \to \pi^0 \upsilon\bar{\upsilon}$ at the SM level. It is with these issues in mind that the KOPIO experiment has been designed. (For more details see the Preliminary KOPIO Technical Design report. [9].)

For any experiment seeking to measure $K_L \to \pi^0 \upsilon\bar{\upsilon}$ the most important means of eliminating unwanted events is to determine that nothing other than one π^0 was emitted in the decay, *i.e.* to veto any extra particles. The most difficult mode to suppress in this manner is $K_L \Rightarrow \pi^0\, \pi^0$ ($K_{\pi 2}$). If this were the only defense against unwanted events, however, an extremely high photon veto efficiency would be required.

Thus, to increase the probability that the source of an observed signal is truly $K_L \to \pi^0 \upsilon\bar{\upsilon}$, another handle is needed. That handle is provided by measurement of the K_L momentum via time-of-flight (TOF). Copious low energy kaons can be produced at the AGS in a time structured beam. From knowledge of the decaying K_L velocity the π^0 can be transformed to the K_L center-of-mass frame and kinematic constraints can be imposed on an event-by-event basis. This technique facilitates rejection of other kaon decays and suppression of all other potential backgrounds, including otherwise extremely problematic ones such as hyperon decays and beam neutron and photon interactions.

The background suppression is achieved using a combination of hermetic high sensitivity photon vetoing and full reconstruction of each observed photon through measurements of position, angle and energy. Events originating in the two-body decay $K_L \Rightarrow \pi^0\, \pi^0$ identify themselves when reconstructed in the K_L center-of-mass system. Furthermore, those events with missing low energy photons, the most difficult to detect, can be identified and eliminated. With the two independent criteria based on precise kinematic measurements and demonstrated photon veto levels, not only is there enough experimental information so that $K_{\pi 2}$ can be suppressed to the level well below the expected signal, but the background level can also be measured directly from data. Evaluation of the KOPIO system leads to the expectation that a signal of about 40 π^0 events, with a S:B of 2:1, will be collected if the SM prediction holds.

The beam and detectors for KOPIO employ well-established technologies. Important aspects of the system are based on previously established measurement technique, while improvements have been studied in beam measurements and with prototypes and simulations. Figure 2 shows a simplified representation of the beam and detector concept. The 25.5GeV primary proton beam will be transported to the kaon production target in 200ps wide pulses at a rate of 25 MHz giving a microbunch separation of 40 ns. A 500μsr solid angle neutral beam is extracted at 45 degrees to produce a "soft" K_L spectrum peaked at 0.65 GeV/c; kaons in the range from about 0.4 GeV/c to 1.3 GeV/c are used. The vertical acceptance of the beam (5 mrad) is kept much smaller than the horizontal acceptance (100 mrad) so that effective collimation can be obtained to severely limit beam halos and to obtain a vertical constraint on the decay vertex position. Downstream of the final beam collimator is a 4 m long decay region that is surrounded by the main detector.

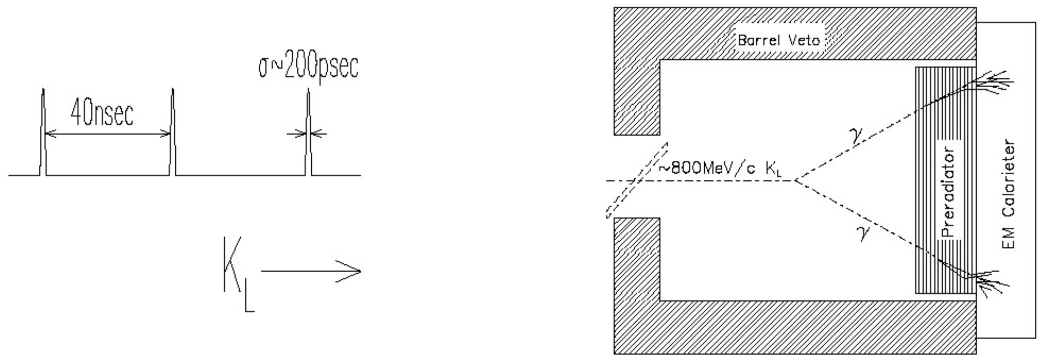


Figure 2. Elements of the KOPIO concept: a time-structured primary beam produces low energy kaons. The decay vertex is determined from the position and direction of converted gammas, which then allows the kaon momentum to be calculated from its reconstructed time-of-flight.

The beam region is evacuated to a level of 10^{-7} Torr to suppress neutron-induced π^0 production. A thin walled vacuum tank encloses a highly efficient charged particle veto system of plastic scintillators surrounding the decay region. Approximately 16% of the kaons decay within this region yielding a decay rate of about 10 MHz. Outside the vacuum are 200 tons of an efficient Pb/scintillator photon veto detector. In order to simplify triggering and offline analysis, only events with the signature of a single kaon decay producing two photons occurring within the period between micro bunches are accepted.

Photons from π^0 decays from $K_L \to \pi^0 \upsilon\overline{\upsilon}$ are observed in a two-stage "pointing calorimeter". It is comprised of a 2 radiation length (X_0) fine-grained pre-radiator calorimeter followed by a 16 X_0 electromagnetic calorimeter. The pre-radiator section obtains the energies, times, positions and angles of the interacting photons from π^0 decay by determining the initial trajectories of the first $e^+ e^-$ pairs. It consists of 64 layers, each 0.034 X_0 thick, composed primarily of a plastic scintillator and a dual coordinate drift chamber. The pre-radiator measures the photon positions and directions accurately in order to allow reconstruction of the K_L decay vertex. In addition, since it is nearly 100% active, the preradiator contributes significantly to the achievement of excellent energy resolution.

The calorimeter located behind the preradiator consists of about 2300 "Shashlyk" tower modules, roughly 11 cm by 11 cm in cross section. A Shashlyk calorimeter module consists of a stack of square tiles with alternating layers of Pb and plastic scintillator read out by penetrating Wavelength Shifting (WLS) fibers. The preradiator-calorimeter combination is expected to have an energy resolution of $2.7\%/(E(GeV))^{1/2}$. Shashlyk is a proven technique that has been used effectively in BNL experiment E865 and is presently the main element in the PHENIX calorimeter at RHIC.

Suppression of most backgrounds is provided by a hermetic high efficiency charged particle and photon detector system surrounding the decay volume. The system includes scintillators inside the vacuum chamber, photon veto detectors surrounding the decay volume, and detectors downstream of the main decay volume, inside and outside of the evacuated region. The photon veto detectors are constructed as Pb/scintillator sandwiches providing about 18 X_0 for photon conversion and detection. The detection efficiency for photons has been extensively studied with a similar system in BNL experiment E787. The downstream section of the veto system is needed to reject events where photons or charged particles leave the decay volume through the beam hole. It consists of a sweeping magnet with a horizontal field; scintillators to detect charged particles deflected out of the beam, and photon veto modules. Aerogel Cerenkov radiators, read out with phototubes, veto photons that leave the decay volume but remain in the beam phase space by taking advantage of the low energy nature of our environment to provide the requisite veto efficiency while being blind to the interactions created by the neutrons and K_L 's left in the beam.

Funding History and Project Status:
The NSF MRE Panel in May 2000, recommended placing RSVP in its highest category for funding in the FY 2002 MRE account. In July 2000, a special Cost Verification Review Panel reviewed the anticipated costs of RSVP and verified the project costs, and in October 2000, the National Science Board unanimously passed a resolution authorizing inclusion of RSVP in the MRE account in the President's Budget in FY 2002 or a subsequent year.

NSF provided funding to develop RSVP starting with a 3-year R&D grant in FY2001 of approximately $400K/year for KOPIO, that included funding for a full-time Project Manager. This has been followed with additional grants of $130K in FY02, and $500K in FY03. In addition the NSF has initiated research support at Virginia Tech and Stony Brook.

The KOPIO Collaboration presently consists of scientists and engineers from 7 U.S. universities, 8 foreign institutions and one U.S. national laboratory.

The general responsibilities of the KOPIO Collaborators will be described in institutional Memoranda of Understanding (MOU). In essence, they will have responsibilities for research and development, engineering design, prototyping, fabrication and normal maintenance and operation of detector systems and components as agreed to and described in the MOU and their addenda.

The KOPIO Project, as it is initially envisioned, is a primarily U.S.-managed effort with substantial collaboration from other countries. Project Management Plan (PMP) will address the current collaboration and accommodate future growth in the collaboration.

Each KOPIO subsystem has a Subsystem Manager (KSM) directly and ultimately responsible for ensuring that the design and construction of the corresponding subsystems are carried out on schedule, within the cost ceiling, and in a way that guarantees the required performance and reliability. Each major KOPIO subsystem will be overseen by a technically-oriented Steering Group, with expertise in all the relevant technical areas.

c. MECO

The MECO Experiment:
The MECO experiment is described in detail in the MECO Draft Technical Proposal (available on the web as part of the review documentation), thus only a brief overview is provided here. MECO is designed to search for the coherent conversion of muons to electrons in the field of a nucleus, $\mu^- N \rightarrow e^- N$, with a rate sensitivity of about 2×10^{-17} times that of muon capture on the same nucleus, $\mu^- N \rightarrow \nu N'$. We know from observation that there is an additive quantum number associated with each type of lepton, the non-conservation of which is commonly referred to as lepton flavor violation (LFV). Searches for LFV processes have been conducted since the discovery of the muon, with ever increasing sensitivity. In the case of muons effectively converting to electrons, for example in

processes like $\mu^+ \rightarrow e^+\gamma$ or $\mu^- N \rightarrow e^- N$, no signal has been seen and current upper limits are at the level of 10^{-11} to slightly below 10^{-12}.

Recently, compelling evidence has emerged that muon and electron number are not, in fact, exactly conserved. However, even if neutrinos mix as the Super Kamiokande and SNO experiments show, the rate for processes of the kind discussed above is very small, well below that accessible in any charged lepton flavor violating experiment. Hence, MECO constitutes a search for the existence of fundamentally new physics.

There has been renewed interest among theorists in LFV in models of physics beyond the Standard Model. Essentially all such models naturally allow lepton flavor violation. For example, recent research in grand unified supersymmetric models has shown that LFV is expected in some of these models at a level that will be experimentally accessible: 10^{-15} in the case of $\mu^- N \rightarrow e^- N$ and 10^{-13} in the case of $\mu^+ \rightarrow e^+\gamma$.

The MECO Construction Project:

The MECO Project will build the detector system, build a new, extremely intense muon beam, and modify the AGS and extraction beam line to produce a facility capable of achieving the scientific objectives described above. We summarize here the principle features of the construction effort.

The proton beam used to produce the required muon beam is described in section 6 above. The AGS extraction "A" line must be extensively modified for MECO. Tasks include removing existing equipment, refurbishing existing magnets, and power supplies, and installing modified beam line magnets, vacuum system, beam monitoring instruments, and shielding. The MECO cost estimate includes funds for D&D of the existing infrastructure. An RF modulated magnet of new design will be developed to remove protons outside the desired pulses and allow monitoring of the performance of the AGS. Two new Lambertson magnets will be built and installed. A counter system will be built to measure the flux and time structure of protons arriving outside of the nominal beam pulses.

A new proton target is required to produce the pions that decay and produce the muon beam. It will consist of a platinum or gold rod installed in a thin water cooling jacket. A 50+ ton copper and tungsten shield will be built surrounding the target and protecting the superconducting magnet in which the target is installed from the heat and radiation produced in the target.

A new, large bore, 5 T peak field superconducting magnet (the production solenoid) will be built to contain the pions and muons inside the shield and direct them into a magnetic transport region. A set of magnets consisting of sections of solenoids and toroids (the transport solenoid) will be designed and built and will serve to guide the beam of muons to the detector region. Electrons will be detected in the evacuated bore of a new superconducting magnet (the detector solenoid) that serves to capture electrons from the conversion process and guide them to a region containing particle detectors that, together with the magnet, comprise a magnetic spectrometer.

The production solenoid has a bore of length of 4 m and diameter 1.5 m. Its maximum field is 5.0 T near the proton beam exit falling linearly to 2.5 T at the entrance to the transport solenoid. The transport solenoid consists of two curved sections and three straights (one at each end and one between the bends) for a total length of approximately 13 m and a clear bore of 0.5 m throughout. The field decreases from 2.5 T at the entrance to the transport to 2.0 T at the exit. The detector solenoid has a

bore length of 10 m and diameter of 1.9 m. Its field is graded from 2.0 T to 1.0 T in the region of the muon stopping target and constant at 1.0 T in the region of the electron detectors.
Three collimators in the straight sections of the transport solenoid serve to restrict passage to muons of the correct charge and momentum range. A thin beryllium window, situated in the second collimator, absorbs anti-protons.

Located in the detector solenoid are the muon stopping target, the tracker, the calorimeter, the muon beam stop, and various absorbers. The stopping target consists of thin Al or Ti foils suspended by low mass supports. Thin, low Z cylinders and cones at large radii are required to shield the electron detectors from low energy protons emitted by the stopping target following muon capture. Some of these are lithium-doped to absorb neutrons. A muon beam stop is required to contain muons that neither stopped in the target nor decayed.

Conversion electrons will be detected and their energies will be measured precisely in a tracking detector installed in the constant field region of the detector solenoid. The tracker has roughly 3000 straws detectors (each about 2.6 m long and 5 mm in diameter) mounted approximately parallel to the axis of the detector solenoid; signals in these detectors are used to determine the r-ϕ track coordinates. Capacitively coupled strips attached to the planes of straw detectors are used to measure the axial coordinate. Roughly 20000 readout channels will be required.

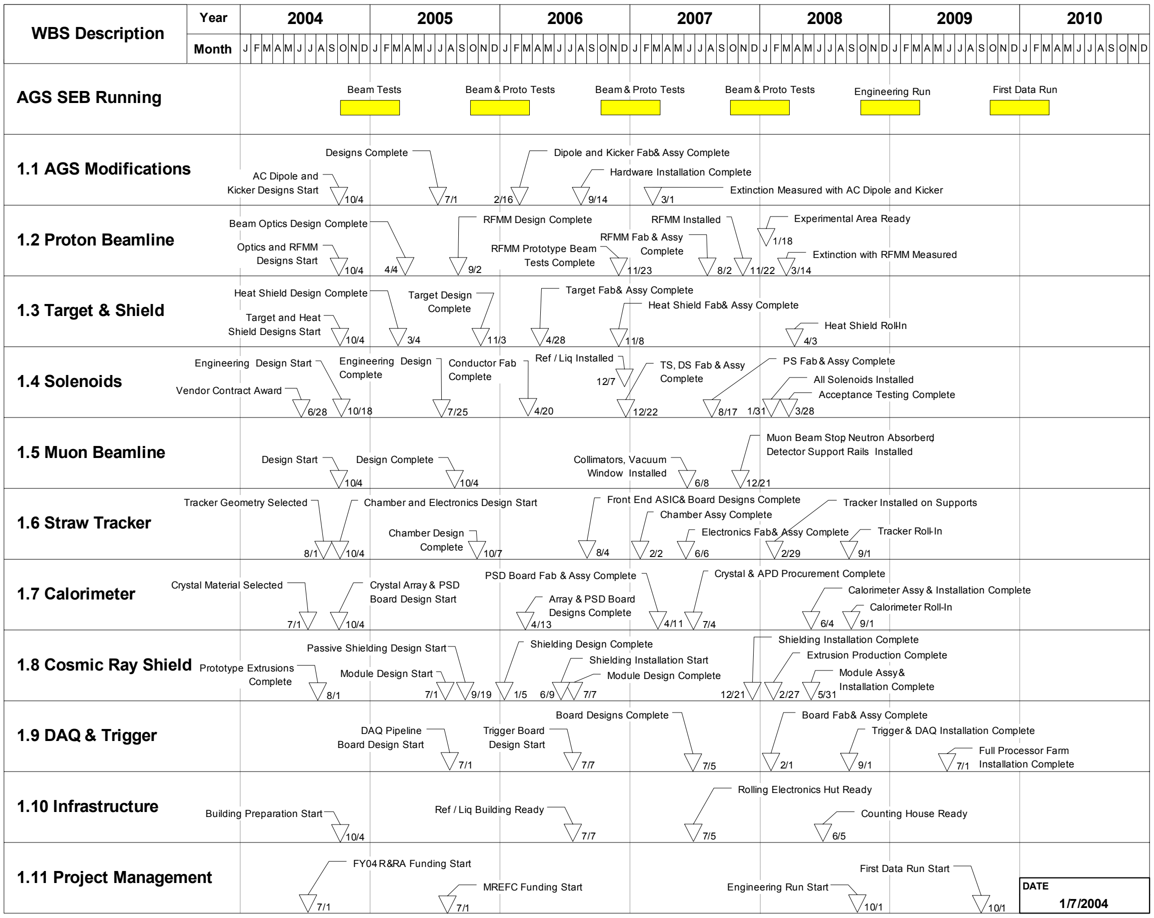
The energy of electrons will also be measured in a calorimeter downstream of the tracker. The calorimeter must have adequate energy and position resolution to suppress accidental background via matching with the electron energy and trajectory as measured in the magnetic spectrometer. The detector approach is a dense crystal detector arranged in four vanes of geometry similar to that of the tracker. Approximately 2000 crystals, each 3 × 3 × 12 cm, are required. Materials being considered include GSO, BGO, and $PbWO_4$. Measuring the light output in a 1.0 T field necessitates the use of avalanche photodiodes. Four thousand channels of ADC readout will be required for the calorimeter.

A cosmic ray shield is required to limit the background from cosmic ray muons interacting in the stopping target or tracking detectors or decaying in the detector solenoid. It consists of both passive shielding and an active scintillator-based veto. Long plastic scintillator panels with wavelength shifter, based on existing designs, must be fabricated.

A new enclosure for the front-end electronics must be built close to the experiment. An existing exterior building must be refurbished for use as the counting house. A data acquisition system and online computing facility must be assembled to record MECO data and allow for data quality control. The centerpiece of this system is envisioned to be a set of approximately 100 computer processors performing high level trigger functions and real time event reconstruction. This will be supported by several workstations for data monitoring and tape handling hardware for data recording. The system of parallel processors will be used for offline data analysis during extended shutdowns and after MECO completes data collection.

The MECO construction milestones for an FY05 MREFC funding start are shown in the figure below. The critical path for the project is defined by the system of superconducting solenoids that enclose the muon beam line. The present estimate is 42 months for final design, construction, installation, and acceptance testing for the magnets. We intend to begin the solenoids' final design effort using pre-project development (PPD) funds as part of the FY04-05 effort, which will allow us to complete installation of all MECO systems in time for the FY09 shake down run. Since the planned use of PPD funds keeps the critical-path magnet construction project on schedule, a delay in MREFC funding to FY06 has reduced impact on the final completion schedule.

MECO Major Milestone Schedule



d. RSVP D&D

The D&D plan for RSVP is to restore the AGS floor to the pre-RSVP condition within a reasonable number of years after the end of experiment operations. It is recognized that the experiments will generate significant amount of beam activated components that will have to be disposed of and a 2-3 year “cool-down” period will be required before D&D can begin.

The slow beam transport will de-commissioned starting at the point where it leaves the switchyard shielding to the RSVP targets, "A" and "B". This will include disconnecting & removing magnets and power supplies, removing cables, vacuum, & instrumentation. All commonly reused valuable equipment such as magnets will be stored except for equipment specific to the RSVP experiments such as the solenoids and the extinction kicker. These will be considered radioactive waste. All shielding activated over 5mr will be considered radioactive waste. The cost of removing and disposing of the experiments will be included. Since building 912 is a multiple use building, shielding under 5mr will be left in the building. All concrete floor areas over 5mr will be removed and replaced, but no radioactive soil remediated. Power and water modifications for RSVP will be removed except where considered an upgrade to existing utilities. The estimated costs are given in section 8 below.

The AGS and Booster will remain operational for RHIC when RSVP is complete so the only D&D envisioned will be for those components added specifically for RSVP and not required for future operations.

7. Incremental Costs and Funding

a. Overall RSVP budget considerations and Operations Cost

The FY04 Presidential Budget Request for NSF included RSVP Project Milestones and Funding Profiles listed on tables I through III. Estimated but unapproved (by NSF) construction costs for KOPIO and MECO showing BNL effort in dollars and FTEs are contained in Table IV. Tables V lists estimated incremental operations costs for the RSVP experiments and Table VI gives the rational for these costs. Table VII lists estimated D&D costs.

BNL has approved the application of the extraordinary construction overhead rates to the RSVP effort. This rate applies to the concept/development and implementation phases of the program commencing in FY 2004. This rate is currently 14.3%. Actual rates will fluctuate, and prevailing rates at the time work is accomplished will be charged. Upon completion of the concept/development and implementation phase of the program, the operations and maintenance phase of this experiment is expected to be the normal BNL overhead rate.

It is anticipated that incremental costs to decommission, decontaminate and deconstruct RSVP will be assessed yearly over the length of the planned operation of the RSVP project, by a panel appointed by the DOE and NSF, with funds placed in a suitable escrow account.

Table I – <u>NSF RSVP Current Project Milestones</u>

Source: NSF Major Research Equipment and Facilities Construction Budget (FY2004 Budget Request)

FY 2005	Complete Magnet Design
FY 2006	Begin Construction
	Complete AGS Design Modifications
	Deliver and Integrate Magnet Coils
FY 2007	Complete Detector Component Prototypes
	Complete Construction of AGS Beam
FY 2008	Start Detector Component Production
	Complete Initial Modules
FY 2009	Complete Data Acquisition System and Trigger Design
	Deliver Detector Components
	Complete Magnet Tests with Installed Detector Elements
FY 2010	Perform Engineering Run
	Complete Construction

Table II – NSF RSVP Funding Profile - R&RA , MREFC

NSF RSVP Funding Profile - R&RA , MREFC

(Millions of Dollars)

	Concept Develop		Implementation		Ops/Maint		Totals		
	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	R&RA	MREFC	Grand Totals
FY2000 and Prior									
FY2001	$0.90	$0.00	$0.00	$0.00	$0.00	$0.00	$0.90	$0.00	$0.90
FY2002	1.20	0.00	0.00	0.00	0.00	0.00	1.20	0.00	1.20
FY2003 REQ	1.20*	0.00	0.00	0.00	0.00	0.00	1.20	0.00	1.20
FY2004 REQ	1.50*	0.00	0.00	0.00	0.00	0.00	1.50	0.00	1.50
FY2005 EST	2.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	2.00
FY2006 EST	2.00	0.00	0.00	30.00	5.30	0.00	7.30	30.00	37.30
FY2007 EST	0.00	0.00	0.00	42.66	8.50	0.00	8.50	42.66	51.16
FY2008 EST	0.00	0.00	0.00	44.00	8.50	0.00	8.50	44.00	52.50
FY2009 EST	0.00	0.00	0.00	20.25	13.50	0.00	13.50	20.25	33.75
FY2010 EST	0.00	0.00	0.00	8.00	14.30	0.00	14.30	8.00	22.30
FY2011 EST	0.00	0.00	0.00	0.00	14.80	0.00	14.80	0.00	14.80
Subtotal R&RA	$8.80		$0.00		$64.90		$73.70		$73.70
Subtotal MREFC		$0.00		$144.91		$0.00		$144.91	$144.91
Total each Phase		$8.80		$144.91		$64.90		$218.61	$218.61

Source: NSF Major Research Equipment and Facilities Construction Budget (FY2004 Budget Request)

***Note: FY03 actual funding was $1m, FY04 Omnibus Bill currently in Senate shows $6M.**

Table III – NSF Funding by Phase

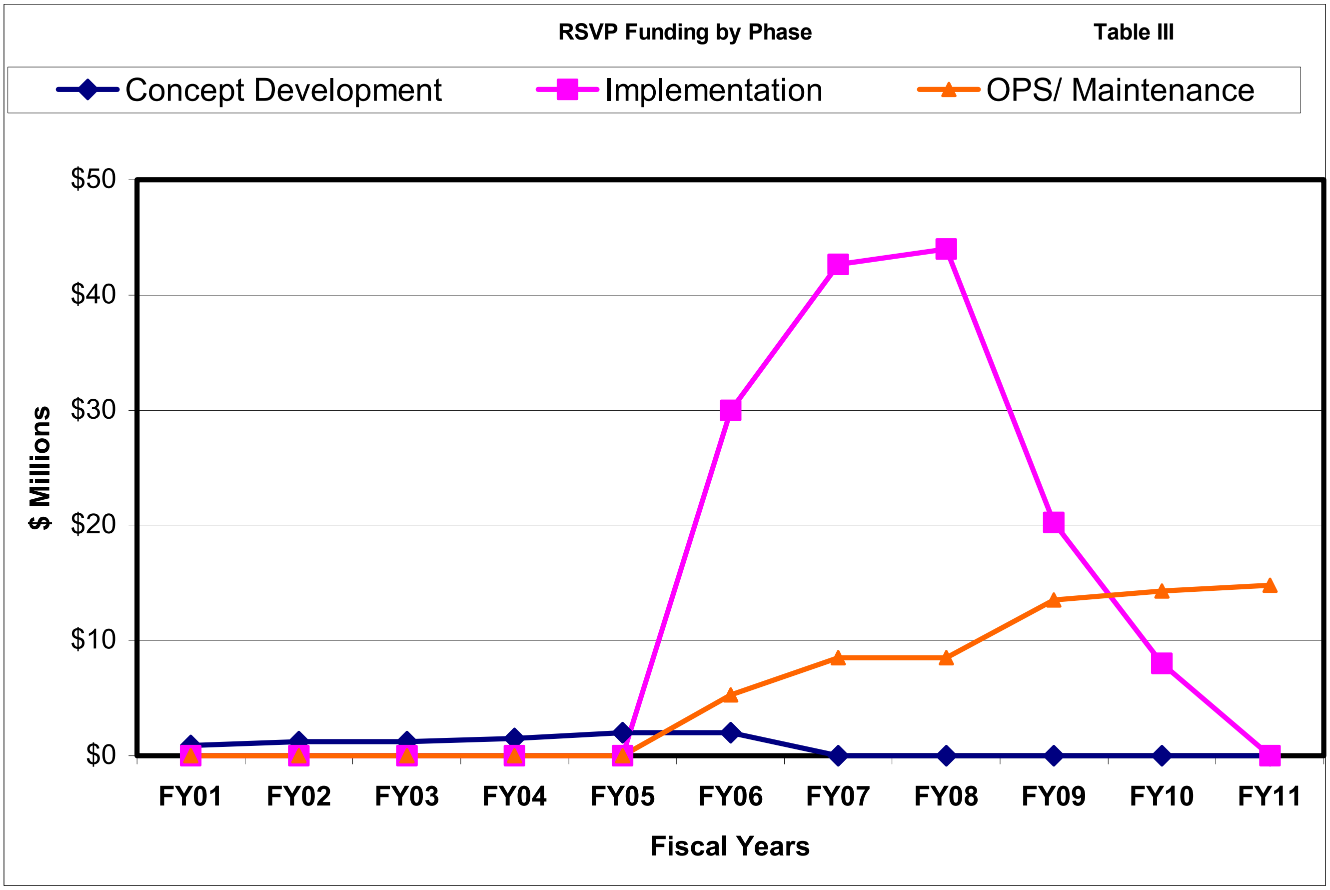


Table IV – NSF Funding by Phase

NSF RSVP, KOPIO and MECO Construction Profile (Draft)
(Dollars in Millions)

Description	FY2006	FY2007	FY2008	FY2009	FY2010	Total
Total NSF KOPIO	$11.5	$16.4	$16.9	$7.8	$3.3	$55.9
C-AD part of above budget	$6.7	$4.3	$2.9	$1.8	$1.6	$17.3
Effort C-AD FTE	16	13	9	8	7	53
Total NSF MECO	$18.5	$26.3	$27.1	$12.5	$4.7	$89.0
C-AD part of above budget	$4.6	$4.0	$2.0	$1.4	$0.1	$12.1
Effort C-AD FTE	18	16	8	6	1	49
Total NSF RSVP (KOPIO/MECO)	$30.0	$42.7	$44.0	$20.3	$8.0	$144.9
C-AD part of above budget	$11.3	$8.3	$4.9	$3.2	$1.7	$29.4
C-AD RSVP FTE's	34	29	17	14	7	102

Table V: C-AD RSVP Estimated Incremental Operations Cost Summary

(Constant FY03 Dollars in Millions, assumes PHENIX decadal run plan is followed and constant effort RHIC budget)

Running Weeks	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014
RHIC WEEKS	27	27	27	27	27	27	27	27	27	27	27
KOPIO WEEKS	1.4	4.3	7	9	6	7	9.5	13.5	10	27	20
MECO WEEKS	1.2	2.6	4	6	7	7	9.5	13.5	17	0	0
Total RSVP Ops Costs	$1.5	$3.9	$6.2	$6.2	$6.7	$6.1	$8.7	$11.0	$12.2	$11.0	$9.0
Total OPS Effort C-AD	0	0	16	16	16	16	18	18	18	16	16
Fixed	0	0	12	12	12	12	12	12	12	12	12
MECO/KOPIO	0	0	4	4	4	4	6	6	6	4	4

RSVP R&D

RSVP Commissioning

RSVP Running

MRE Construction

Table VI Rationale and Manpower to Operate AGS for RSVP

Rationale

The costs to construct and operate the RSVP experiments are calculated incremental to the costs of RHIC operations. This incremental and cost sharing model had been the case at the AGS, for the period of 1986-2002, between HEP and NP during the pre-RHIC and into the RHIC era. AGS fixed target operations costs are based on past experience with HEP and NP experiments as well as NASA, NNSA and BES experiments. The cost estimates to follow cover the various running scenarios envisioned for the RSVP experiments and are based on the following assumptions.

- AGS slow extracted beam (SEB) operations for RSVP will run concurrent with RHIC collider operations when possible. Running concurrent with RHIC operations will require base personnel support for the AGS fixed target operation. Without base support short runs are costed on a per hour basis (full cost recovery) for personnel and materials and scheduled outside of RHIC operations. Such runs are considered on a case by case basis and carried out only if the impact on RHIC shutdown work is minimal.

- During RHIC injection all other machine operations will cease, so as to allow full attention to this process. This mode of operation was commissioned in FY 2001 with the successful operation of the AGS as a heavy ion injector for RHIC and for high intensity proton (SEB) for three AGS fixed target experiments. Switching times of order 15-30 minutes have been demonstrated. This should result in about 100 hours per week for SEB.

- The NSF HEP program operations are calculated as an incremental cost to the base NP support of RHIC injector operations.

- The NSF will incrementally support the power costs for SEB, beam transport and experimental area operations. The standby AGS power consumption of 7 MW (RHIC Operating with protons) or 5 MW (RHIC Operating with HI) is billed to RHIC operations. The additional flattop, extraction system, beam transport and experiment power is billed to the NSF. Power costs are billed on an actual use basis whereas other costs, personnel and materials, are billed according to previously established average costs. Power costs are assumed to be fixed at $55/MWhr through July 2005 and $85/MWhr thereafter. Our present NYPA contract will expire in July 2005 and $85/MWhr is the guidance we've been given by the laboratory. Note this rate is still significantly less than the Long Island homeowner pays.

- Most accelerator manpower is covered by RHIC operations. Main control room operations is sufficient to cover SEB operations during RHIC collision operations. There are no manpower charges except for an incremental effort to support the SEB extraction system.

- The RHIC program does not support any manpower for AGS experiments. NP has not budgeted test beam support for its own program. All experimental area manpower support will be billed to the NSF. The manpower costs that are shown below consist of a base manpower level that supports the extraction system, switchyard transport, primary proton transport and the primary target area. The incremental manpower cost for an experiment is explicitly identified. The additional HEP manpower is matrixed into the Collider Accelerator Department staff.

- M&S, DTS and special procurement for AGS/Experiment concurrent with RHIC operations is charged incremental to RHIC. It is assumed RSVP is on 80% of the time (i.e. off during RHIC fills).

- M&S, DTS and special procurement for RSVP operation outside of RHIC operations is fully charged (no RHIC help). Only shift differential (15%), however, is charged for accelerator machine operations staff.

- Capital construction costs are fully borne by the NSF. This includes experiment construction, AGS modifications, and beam line construction costs and are in addition to the costs outlined here.

The RHIC schedule for FY2005 and beyond is not set. The optimal RHIC operations plan calls for 37 weeks per year of RHIC cryogenic plant operation but the required funding to do this has not materialized. Consequently, for this exercise, a constant effort 27 weeks per year RHIC running scenario is assumed. Of the 27 weeks, only 24 weeks are available for RHIC beam activities since 3 weeks are required for cool-down and warm-up of the RHIC magnets. Furthermore, 5 weeks of intense beam development are generally required to establish stable physics running conditions for RHIC for each beam species used. So, if one beam species is used by RHIC then that will leave a net 19 weeks available for AGS fixed target experiments and if two beam species are used by RHIC experiments this will result in 14 weeks available for AGS fixed target work. Running outside of RHIC operations is possible and will be considered on a case-by-case basis. The issue is impact on RHIC shutdown activities and possible power curtailment agreements (a summer issue). For planning we assume the RSVP experiments could operate for up to about 8 weeks/year in this mode.

Manpower

The base manpower estimate is comprised of the following:

	FTE
Physicist	1
Engineering (mechanical, electrical)	1
Controls	0.5
Instrumentation	1
Vacuum systems	0.5
Magnet systems	1.5
Power supplies	1.5
Utilities (power, water, AC)	2
Extraction systems	1
ES&H, QA, Admin, training (org. burden)	0
Shift operations	2
Total	12

E926 manpower support

Physicist, engineering	1
RF systems (microbunch)	1
Technicians (inst., vacuum, magnet etc.)	2
Total	4

E940 manpower support

Physicist, engineering		1
Cryogenic engineering, technicians	3	
Technicians (insert., vacuum, magnet etc.)	2	
Total	6	

Table VII – RSVP D&D Costs

The below costs are in millions of FY 2003 dollars, fully burdened

Experiment	**Estimated D&D Cost**
K0PI0	$5.3
MECO	$5.3
Contingency	$2.7
Total Estimated Cost	**$13.3**

b. KOPIO Construction Costs:

The KOPIO Project has developed a bottom's up cost estimate based on a WBS that includes all facets of the project. In July 2000, a special Cost Verification Review Panel of eight experts, including several major project managers, reviewed the anticipated costs of RSVP and verified the project costs at the ~10% level of accuracy. In June, 2001, NSF held a full scientific and technical review of RSVP, recognizing that pre-MRE R&D support was critically needed to bring RSVP into readiness for possible MRE funding. The review panel expressed strong support for the strengthened management. On 14-15 March 2002, a "cost control" review committee (chaired by Jim Yeck and including Gary Sanders Richard Ehrlich (Cornell) and Karol Lang (Texas)) concluded that RSVP "progress to date has been exceptional. The WBS Cost breakdown was updated and reviewed by an NSF Panel at Irvine in January 17-18, 2003.

c. MECO Construction Costs

MECO has prepared a detailed Work Breakdown Structure for all tasks associated with the construction effort, including AGS modifications and construction of the new proton beamline, as well as management tasks including quality assurance, cost and schedule tracking, integration, and safety. A bottoms up cost, including detailed contingencies, for the effort described by that WBS was completed prior to the June 2001 NSF review of RSVP and revised for the January 2003 RSVP review at UCI. The estimated cost coincides with MECO's portion of the MRE-FC budget profile as outlined in the NSF's FY04 Budget Request to Congress.

Appendix I – RSVP/E949 Review Charge and Instructions from DOE

I. DOE ONP Charge Document of November 24, 2003

United States Government **Department of Energy**

memorandum

DATE: November 24, 2003

REPLY TO
ATTN OF: Office of Science

SUBJECT: DOE Review of the Rare Symmetry Violating Processes Project Activities at Brookhaven National Laboratory

TO: Daniel Lehman, SC-81

I would like to request that your office conduct a review to assess the impact of the proposed Rare Symmetry Violating Processes (RSVP) project on the current Relativistic Heavy Ion Collider (RHIC) activities at Brookhaven National Laboratory (BNL).

As you know, the Office of Science (SC) Nuclear Physics (NP) program supports the operations of the RHIC facility at BNL. The National Science Foundation (NSF) is proposing to construct and operate two experiments, the RSVP project, that would utilize the Alternating Gradient Synchrotron (AGS) facility which is the injector for and an integral component of the RHIC facility. The SC Nuclear Physics program welcomes the opportunity to make available the capabilities of its facilities for meritorious non-NP activities, as long as these activities do not have a negative impact on the facility's ability to successfully carry out the primary mission for which it is funded.

A Memorandum of Understanding between NSF and DOE is in preparation to define the scope and the roles and responsibilities of the agencies. The high scientific merit and priority of RSVP have been ascertained and well documented by peer-review, including the NSF National Science Board. The NSF proposal includes funding to construct and commission these experiments, including the incremental operating costs for their research program. In order to proceed, the Nuclear Physics program needs to understand the impacts related to mutual compatibility of the construction, commissioning and operations of RSVP and RHIC's nuclear physics mission, both short- and long-term.

In this context, I request that your office conduct a review of these impacts. In particular, the review committee should assess the risks and impacts (both positive and negative) of the proposed RSVP construction project and RSVP operations on the RHIC accelerator complex and RHIC nuclear physics program at BNL, including other ongoing work-for-others activities that utilize the RHIC accelerator complex such as the NASA Space Radiation Laboratory. This assessment should include NSF expectations of beam time for the RSVP program and identify the incremental costs to NSF for this running time.

I have asked Jim Hawkins of my office to work with you on this review. I would like the review to take place by the end of January 2004 and would appreciate receiving your committee's report within 60 days of the review's conclusion.

[SIGNED]

Dennis G. Kovar
Associate Director of the Office of Science
for Nuclear Physics

cc: Tom Kirk, BNL
Peter Paul, BNL
Michael Holland, BAO
Joe Dehmer, NSF
Marvin Goldberg, NSF
Robin Staffin, SC-20
Aesook Byon-Wagner, SC-20

II. Additional Material Supplied by DOE Office of Nuclear Physics, December 11, 2003

Subject: RSVP Review
Date: Thu, 11 Dec 2003 18:05:59 -0500
From: "Kovar, Dennis" <Dennis.Kovar@science.doe.gov>
To: "Tom Kirk (tkirk@bnl.gov)" <tkirk@bnl.gov>
CC: "Lehman, Daniel" <Daniel.Lehman@science.doe.gov>,
"Steadman, Stephen" <Stephen.Steadman@science.doe.gov>,
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"Goldberg, Marvin" <mgoldber@nsf.gov>,
"Brad Keister (bkeister@nsf.gov)" <bkeister@nsf.gov>,
"Byon, Aesook" <Aesook.Byon@science.doe.gov>

To: Tom Kirk
From: Dennis Kovar
Subject: RSVP Review

Regarding the upcoming Lehman review of the impacts and incremental costs of the RSVP project, BNL needs to provide a written response by Wednesday, January 12, 2004 addressing the November 24, 2003 charge letter to Daniel Lehman. This written response will be reviewed and evaluated by the review committee during the review scheduled for January 27 and January 28. All supporting documentation should also be available by January 12, including the MECO and KOPIO management plans, documents that identify all resources (costs, funding, and manpower) required to support MECO and KOPIO, and a decommissioning and disposal (D&D) analysis of the work that will need to be accomplished at the completion of the RSVP program. Because NSF is also considering sponsorship of the continuation of AGS experiment E949 under equivalent administrative conditions, we intend to consider the RHIC program impacts of this experiment in the same review, using the same tools. We, therefore, ask that the equivalent E949 documents be made available to the committee.

The response should cover the RSVP project and operations program which includes the experiments KOPIO, MECO, and E949. In addition, the response should include a spreadsheet that captures all of the relative incremental yearly costs associated with the life-cycle cost of the RSVP project and the AGS. These incremental costs should include appropriate items associated with commissioning, operating, maintenance, capital reinvestment, waste disposal, and final disposition (D&D). As per the draft MOU between DOE and NSF, the cost to decommission, decontaminate, and deconstruct this project will be assessed in yearly amounts over the length of the planned operation, with funds placed in a suitable escrow account.

If you have any questions, please contact Stephen Steadman or Jim Hawkins within my office.

Cc:
Daniel Lehman
Stephen Steadman
James Hawkins
Marvin Goldberg
Derek Lowenstein
Brad Keister
Aesook Byon-Wagner

Appendix II – Preliminary Agenda for the Review

(Revised January 25, 2004)

DOE Review of the RSVP Activities at BNL
Brookhaven National Laboratory
January 27-28, 2004

Tuesday, January 27, 2004		**Berkner Rm. B**
08:00 am	DOE Executive Session	
	Remarks	M. Holland
08:30 am	Welcome	P. Chaudhari
08:40 am	Overview of RSVP Project	J. Sculli
09:00 am	RSVP at BNL	T. Kirk
09:15 am	Work for Others (WFO) at AGS – NSRL Experience	D. Lowenstein
9:45 am	Coffee Break	
10:00 am	DOE-BAO Site Office Oversight	R. Desmarais
10:15 am	RHIC/RSVP Experimental Ops. & RSVP Installation	P. Pile
11:00 am	RHIC/RSVP Accelerator Ops. & RSVP Modifications	T. Roser
12:00 pm	DOE Working Lunch	**Berkner Rm. A**
1:00 pm	Parallel Sessions *	
	Experiments/Beamlines Topics	**Berkner Rm. B**
	Topic	Discussion Leader
	- Construction/Installation/D&D Periods	Al Pendzick
	- E949 Preparations/D&D	Al Pendzick
	- RHIC-RSVP Interactions (Benefits & Risks) (this discussion includes Accelerator group)	Phil Pile
	Accelerator Topics	**Berkner Rm. C**
	Topic	Discussion Leader
	- RHIC operations performance and plans	Wolfram Fischer
	- Extraction and primary beam transport commissioning	Kevin Brown
	- Machine R&D for RSVP	Leif Ahrens
	- AGS operations with RHIC	Kip Gardner

* Experts from C-AD and the experiments will be present during these sessions

4:30 pm	DOE Executive Session	**Berkner Rm. B**
5:30 pm	Committee Questions for Presenters	
6:00 pm	Adjourn	
Wednesday, January 28, 2004		**Berkner Rm. B**
08:30 am	Answers to Committee Questions	
09:00 am	DOE Executive Session	
12:00 pm	DOE Working Lunch	**Berkner Rm. D**
1:00 pm	DOE Executive Session (Cont.)	
02:00 pm	Closeout With BNL and RSVP Management	
02:30 pm	Adjourn	

Appendix III – Web References

Supporting documentation, including the MECO and KOPIO proposals, draft technical design reports, floor layouts etc. can be found on the web. The relevant links are given below.

http://www.phy.bnl.gov/review/doe-np_040127

Public Web Pages:

K0PI0: http://pubweb.bnl.gov/people/e926/

MECO: http://meco.ps.uci.edu/

RHIC: http://www.bnl.gov/RHIC/

RHIC Luminosity Plot (Present Run):
http://www.agsrhichome.bnl.gov/AGS/Public/QtrReports/rhic_perf/IntegratedLuminositybyYear04.pdf

Appendix IV – Reviewer List

Department of Energy Review
of the Rate Symmetry Violating Processes (RSVP) Project
January 8, 2003
REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Daniel Lehman, DOE/SC, Chairperson	**301-903-4840**	**daniel.lehman@science.doe.gov**
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*Peter Limon, Fermilab	630-840-3340	pjlimon@fnal.gov
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Subcommittee 3: Management

*Ronald Lutha, DOE/FAO	630-840-8130	ronald.lutha@ch.doe.gov
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* Subcommittee Chairperson
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